

Continuity Tester

a component-friendly design

By H. Barteling

A continuity tester is a useful bit of kit for any electronics enthusiast but many of the off-the-shelf models you can buy suffer from one serious disadvantage: they can end up destroying the component under test!

Most silicon semiconductor junctions start to conduct when the forward voltage across the junction exceeds about 0.6 V, but other devices such as Schottky diodes conduct with a much lower forward voltage. If insufficient care has been taken in the design of a continuity tester to reduce the measuring current flow then the component probed can become electrically stressed and may fail. The design presented here produces a measuring voltage of just 5 mV into a test resistance of 10 Ω . In theory the measuring voltage can rise to a maximum of approximately 0.8 V (the battery voltage, V_B , less V_{be} , the voltage drop across the base-emitter junction of one transistor) but the measuring current will always be limited to safe value of 0.6 mA to avoid damage to the component under test.

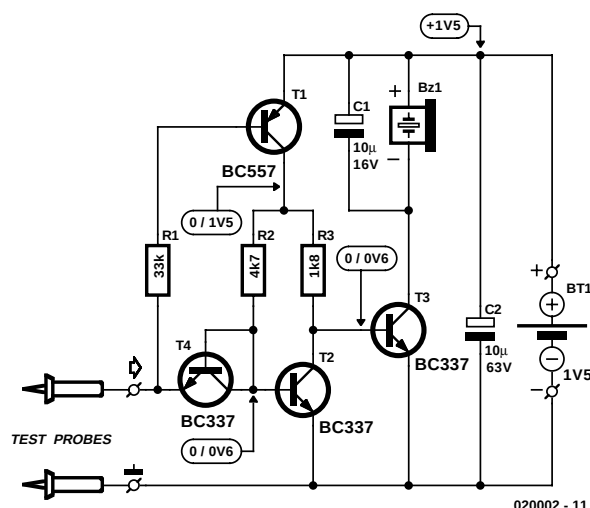


Figure 1. Circuit diagram for the current mirror continuity tester.

COMPONENTS LIST

Resistors:

R1 = 33k Ω

R2 = 4k Ω 7

R3 = 1k Ω 8

Capacitors:

C1, C2 = 10 μ F 16V radial

Semiconductors:

T1 = BC557

T2, T3, T4 = BC337 or BC347

Miscellaneous:

BT = AAA 1.5V battery with holder

Bz1 = DC buzzer for 5-6 V

Length of PVC electrical wiring pipe (used as case)

PCB, order code **020002-1** (layout available as a free download from www.elektor-electronics.co.uk)

A single 1.5 V battery powers the complete circuit and when there is no conducting path between the probes so little current flows that an on/off switch is unnecessary. A 5-V piezo buzzer is used to indicate when continuity is detected (operation at 1.5 V was found to be not a problem for the buzzer).

The current mirror

Figure 1 shows the circuit diagram for the continuity tester. Transistors T4 and T2 together with resistors R2 and R3 are connected in a current mirror configuration. The current mirror is a basic building block of electronic design and deserves a

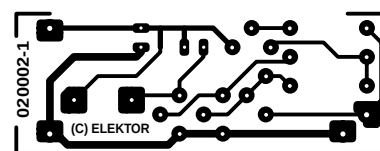
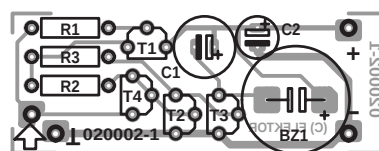


Figure 2. The PCB fits neatly into a small length of plastic conduit.

Reflections on the current-mirror

The current-mirror configuration is a fundamental circuit in electronic design and is a variant of the constant current source circuit. **Figure A** shows a constant current source circuit where the output current I_o is a function of the base-emitter voltage V_{be} of the transistor and the emitter resistor R_e expressed in the formula:

$$I_o = (V_B - V_{be})/R_e$$

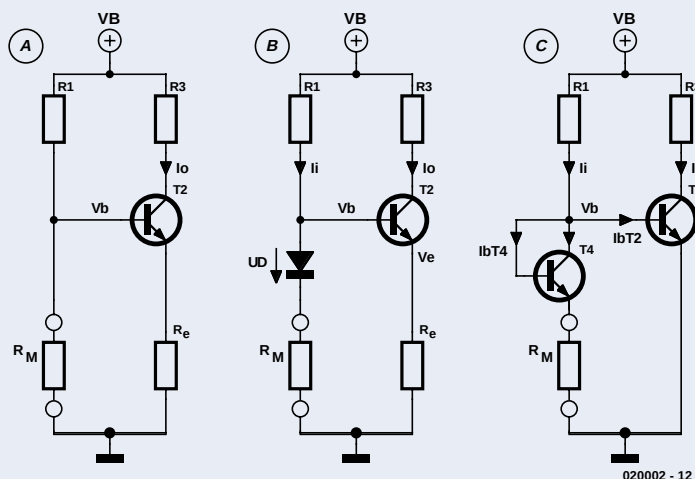
This current source is not too stable because it ignores the fact that the V_{be} for the transistor varies with temperature by a coefficient of $-2 \text{ mV}/^\circ\text{C}$. If we could somehow vary the base voltage V_b with temperature to compensate exactly for this drift in the transistor characteristics then the current source would be more stable. The standard method of achieving this is to include another p-n junction (it could either be a silicon diode or better still a transistor with its base and collector shorted together) in the voltage generator that produces V_B . This ensures that V_B will track with V_{be} so that their difference ($V_B - V_{be}$) will be constant as the temperature changes. The constant current generator shown in **Figure B** includes this modification and is very close to our final current mirror circuit. The output current I_o is proportional to the input current I_i and the scale factor of this current is given by R_M/R_e so that

$$I_o \approx R_M/R_e \times I_i$$

The current flowing into the base of T2 is so small it can be ignored. The circuit can also function without an emitter resistor (with a loss of accuracy, however). **Figure C** is now the basic circuit of our continuity tester where the input and output current are:

$$I_o \approx I_i$$

R_M is the measured resistance between the probes and will be either an open-circuit (no input current will flow) or a short-circuit, in which case the input current will be governed by the value of R_1 and the supply (battery) voltage V_B .



closer look.

Transistors have two p-n junctions, one between the base and emitter and another between the base and collector. If we connect the base and collector leads together then one of these p-n junctions is shorted out and the transistor is left with only one junction... that's right, it has turned into a diode! If this

diode were made from one of a pair of matched transistors then its forward conduction characteristics will be identical to the base-emitter characteristics of its transistor twin. When a current is passed through the diode a voltage will be developed across it corresponding to the current. If this voltage is applied to the base of its matched transistor

twin, its collector current will be the same (mirrored) as the current through the diode.

To analyse the circuit operation we can firstly assume that a low impedance or short circuit exists between the test probes. In this case transistor T1 will conduct and supply power to the current mirror via R2 and R3. The emitter of T4 will be very close to ground potential so current will flow through R2 and T4 to ground. The voltage produced at the base of T2 will cause the same level of current to pass through the collector of T2. The values of resistors R2 and R3 are not the same so that more current will flow through R3. A portion of this current will pass through T2 but the voltage at the collector of T2 will be sufficient to cause T3 to conduct and switch on the buzzer.

If we now connect a resistor of a few hundred ohms between the probes, the current through this external resistance is supplied partly by T1 (approximately $30 \mu\text{A}$) and partly by R2 and T4 (approximately $500 \mu\text{A}$). The additional voltage drop across the external resistor will be added to the base voltage at T2 causing it to fully conduct and turn off transistor T3 and the buzzer.

Finally, when the probes are open-circuit, no current will flow into the base of T1 so it will not conduct and the supply to the current mirror circuit and buzzer will be switched off.

In practice

So from the theory, if the circuit is to operate correctly, it is important the two transistors used in the current mirror should be the same. This means that they should have matching characteristics, not only the type of transistor but also the same gain category (usually denoted by A, B or C suffix for the transistor) and if possible from the same production batch (same batch number or production date). The current mirror configuration is so common in high quality amplifier and instrument designs that matched pairs are available supplied in the same package outline. This ensures not only that the properties of both transistors are as alike as possible but also that they are in good thermal contact so that the characteristics of both transistors track together over temperature. Such accuracy is not necessary for our design here. Resistor R3 can be adjusted to ensure that the piezo buzzer only sounds when continuity is detected between the probes.

Construction and testing

Fitting the components to the PCB shown in **Figure 2** should present no great problems; it is only advisable not to fit R3 too closely to

the board initially because it may need to be changed. Once the cables, test probes and battery have been fitted you can proceed with the set-up. The voltage levels shown on the circuit diagram refer to the voltage levels that can be measured when the when the buzzer is respectively silent or buzzing. Fit leads for the test probes and wire the battery to the circuit. Touching the test probes together should cause the buzzer to sound but if this does not happen then experiment by soldering a resistor in parallel with R3 to reduce its value. The combined resistance of R3 should not be less than 1 k Ω .

The buzzer should be silent when the

resistance between the probes is greater than about 10 Ω . Connect a resistor of this value between the test probes and if the buzzer sounds then unsolder one leg of R3 and add an additional resistor in series with it. The final value of R3 is not too important as long as it is less than about 22 k Ω . Don't be in too much of a hurry to test the unit after soldering because some of the components are sensitive to heat and correct circuit operation is not guaranteed until the components have returned to room temperature.

If you have no success by changing the value of R3 then try swapping transistors T2 and T4, if this does not do the trick then try exchanging these transistors for other examples that you may have.

When you are happy that the tester is working correctly, pop the PCB and battery into a small length of plastic tubing (plastic conduit) and fit a cork to both ends to secure the PCB, not forgetting to make an opening to allow the leads to pass outside to the probes.